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(71) Applicant (*for all designated States except US*): IMPLICO B.V. [NL/NL]; Prinses Irenestraat 61, NL-1077 WV Amsterdam (NL).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): FULS, Paul, Fritz [ZA/ZA]; 19 Barnstable Road, Lynnwood Manor, Pretoria, Gauteng Province (ZA).

(74) Agent: SMULDERS, Th., A., H., J.; Vereenigde Octrooibureaux, Nieuwe Parklaan 97, NL-2587 BN The Hague (NL).

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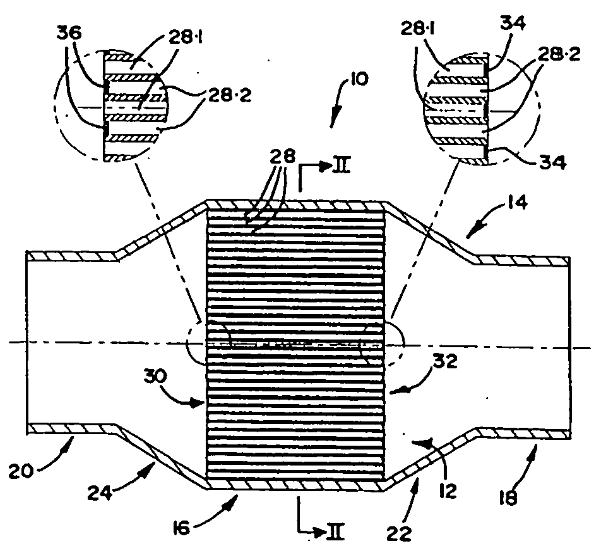

(57) Abstract

A ceramic catalytic convertor catalyst support (12) comprises an elongated open-porous matrix (26) containing a catalyst supported in its interior and provided with lengthwise passages (28) opening out at an end (30, 32) of the matrix. Each passage (28) is constricted (34) nearer to the end of the matrix opposite the open end of the passage, some passages (28.1) opening out of one end (30) of the matrix and some (28.2) opening out of the other end (32) of the matrix. The constrictions (34) in the passages act to promote flow of gas, entering open ends of the passages (28.2) at one end (32) of the matrix, in a direction transverse to the passages and through the porous interior of the matrix into passages (28.1) having open ends at the opposite end (30) of the matrix.

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Title : Catalytic convertor

THIS INVENTION relates, broadly, to catalytic conversion for the treatment of exhaust gases of fuel combustion engines. More particularly, the invention relates to ceramic catalyst supports for catalytic convertors, suitable for the treatment of exhaust gases from fuel combustion engines such as diesel- or gasoline-driven internal combustion engines; and the invention relates further to such supports in the form of ceramic catalyst cores or supports for such convertors and forming part of such convertors.

According to one aspect of the invention there is provided a ceramic catalyst support for supporting a catalyst for the catalytic conversion of a substance passing through the support, the support comprising a ceramic matrix which has an open porous interior comprising open-ended pores, the support having a plurality of passages extending along its interior in a direction which extends from an end of the support towards another end of the support, each passage opening out of at least one end of the matrix and a plurality of the passages opening out of each end of the matrix, at least some of the passages being constricted by constrictions at positions closer to the one end of the matrix than to the other end of the matrix and opening out of said other end of the matrix, and at least some of the passages being constricted by constrictions at positions closer to said other end of the matrix than to said one end of the matrix and opening out of said one end of the matrix, the constrictions of the passages acting to promote flow of gas entering the open ends of constricted passages at the end of the matrix remote from their constrictions, in a direction transverse to the passages and through the porous interior of the matrix material and into

passages having open ends at the opposite end of the matrix and remote from their constrictions, and thence out of the matrix via said open ends at the opposite end of the matrix.

According to another aspect of the invention there is provided a ceramic catalyst support supporting a catalyst for the catalytic conversion of substances passing through the support, the support comprising a ceramic matrix which has an open porous interior comprising open-ended pores, and the support comprising a catalyst for the catalytic conversion of substances passing through the support, the catalyst being supported by the support in the pores on the surfaces of the pores in the porous interior of the matrix.

The support may comprise both the passages and the catalyst as set forth above, the support thus having a plurality of passages extending along its interior in a direction which extends from an end of the support towards another end of the support, each passage opening out of at least one end of the matrix and a plurality of the passages opening out of each end of the matrix, at least some of the passages being constricted by constrictions at positions closer to the one end of the matrix than to the other end of the matrix and opening out of said other end of the matrix, and at least some of the passages being constricted by constrictions at positions closer to said other end of the matrix than to said one end of the matrix and opening out of said one end of the matrix, the constrictions of the passages acting to promote flow of gas entering the open ends of constricted passages at the end of the matrix remote from their constrictions, in a direction transverse to the passages and through the porous interior of the matrix material and into passages having open ends at the opposite end of the matrix and remote from their constrictions, and thence out of the matrix via said open ends at the opposite end of the matrix, and the support comprising

a catalyst for the catalytic conversion of substances passing through the support, the catalyst being supported by the support in the pores on the surfaces of the pores in the porous interior of the matrix. The surfaces of the passages may, if desired, be provided with a relatively rough texture, eg by providing it with an adherent lining, which may be formed from particles and/or may be porous, to permit enhanced proportions or surface densities of catalyst to be supported on said surfaces, compared with passages with smooth surfaces. The support may have various shapes, being eg a flat plate or disc, or being more or less elongated, in the form of a block or cylinder.

The constrictions can act merely to throttle the passages by reducing the cross-sectional area thereof available for gas flow along them, or the constrictions can act to block and close off the passages, to prevent gas flow along them. The degree of constriction will be selected, together with the porosity of the matrix material, the spacing of the passages from one another and the cross-sectional areas of the passages, to promote a desired degree of said transverse gas flow through the porous interior of the matrix material, compared with any gas flow which takes place along the passages from one end of the matrix to the other without entering the porous interior of the matrix. If all the passages are blocked, then all the gas entering the matrix via open ends of passages will at some stage flow transversely through the porous material of the matrix, but if at least some of the passages are not blocked and are merely throttled or not constricted at all, then some gas can pass straight through the matrix along such passages, without entering the porous interior of the material at all.

A variety of options is thus available. Thus, passages which are blocked may open out of only one end of the matrix or out of both ends, while passages which are throttled will open out of both ends. The

passages may comprise exclusively blocked passages or exclusively throttled passages, or a mixture of blocked passages and throttled passages, and the matrix may have some unconstricted passages opening out of both ends thereof, so that all three types of passages are present. The passages need not all be of the same cross-sectional outline or of the same cross-sectional area and such area of a passage need not remain constant in magnitude or shape along its length. Thus, some passages may be narrower or broader than others, whereas some may be of circular cross-section and/or others may be of square/rectangular or even star-shaped cross-section. It will thus be appreciated that there is considerable freedom, in terms of the invention, to vary the size and shape of the passages, the positions thereof in the matrix and the numbers and spacing thereof from one another, and the porosity of the matrix, to promote a desired pattern of gas flow from one end of the matrix to the other, at least some of the gas passing through the porous interior of the matrix.

In a particular embodiment of the invention substantially half the passages may open out of one end of the matrix, the matrix optionally being elongated and straight, the passages extending to the other end of the matrix, at which other end of the matrix they are closed off, the remaining substantially half of the passages opening out of said other end of the matrix and extending substantially all the way to said one end of the matrix, where they are closed off, the passages all being of the same cross-sectional area which is constant along their lengths and all being of the same cross-sectional outline, the passages all being substantially equally spaced from one another and extending alongside one another between the ends of the matrix, the passages being arranged so that, except adjacent a surface of any side of the matrix between its ends, each tube opening out of the one end of the matrix is surrounded by tubes opening out of the other end of the matrix and each tube opening

out of the other end of the matrix is surrounded by tubes opening out of the one of the matrix, the passages adjacent the surface of any side of the matrix being only partially so surrounded. By substantially half the passages is meant 49 - 51% thereof, and it should be noted that the matrix can have a single side if it is non-polygonal in cross-section, eg circular, elliptical or the like in cross-section, or it can have several sides, eg if it is polygonal in cross-section.

In this particular embodiment the matrix preferably has a circular cross-section, and a diameter of 50 - 150 mm, typically 80 - 150 mm, eg 110 mm, although naturally, it may, instead, be square, elongate rectangular, elliptical or oval or of some other desired cross-section, being nevertheless of a cross-sectional area similar to those of the circular cross-sections specified above, the matrix having a length of 50 - 200 mm, typically 80 - 120 mm, eg 100 mm, the passages having a circular cross-section and a diameter of 2 - 10 mm, typically 2 - 6 mm, eg 4 mm, being equally spaced from one another, eg in a square- or hexagonal grid arrangement by a spacing, between adjacent passages, of 1 - 10 mm, typically 3 -6 mm, eg 4 mm, this spacing providing a measure of the thickness of the matrix material between adjacent passages. Naturally, passages of other cross-sections (eg square, elongate rectangular, elliptical, oval, star-shaped etc) may be used instead, but will typically be of the same cross-sectional area and spacing/arrangement as described above for circular cylindrical passages. Furthermore, not all the features of this preferred embodiment need be employed simultaneously, and one or more of them may, if desired, be altered or omitted.

When all the passages of the matrix are blocked or closed off, this is suitable for treating fluids which are sufficiently free of solids such as entrained particles, eg ash or soot, which can blind the pores of the

matrix. When such particles are expected, the passages which receive fluid via their open ends and which form fluid inlet passages into the matrix can be open at both ends, being constricted eg by tapering or by having waisted or venturi-shaped constrictions at their downstream ends, to permit particles to issue therefrom so that particle build-up therein is resisted. Naturally, the passages opening out of the downstream end of the matrix and which form outlet passages from the matrix and which receive fluid from the porous interior of the matrix can be closed off or blocked at their upstream ends, if desired. A matrix having its inlet passages unblocked and not closed off, and its outlet passages blocked or closed off at their upstream ends, can, in principle, in addition to being self-cleaning of particles, also be used to separate particles such as ash or soot, from eg flue gases or diesel exhausts, gases containing particles and issuing from the downstream ends of the inlet passages being kept separate from clean gases issuing from the outlet passages, thereby to clean at least part of the gases in question.

The matrix material will have an open porous interior made up of open pores, capillaries or tubules which are interconnected to one another and, except for negligibly few exceptions, are not closed off and isolated from one another, and which open out of openings at the surface of the matrix, may have an average pore size of 1 - 40 μm, preferably 3 - 20 μm, eg 7 μm. In this regard the terms 'pores' and 'porous' are thus not limited to the openings out of the surface of the matrix, but include also the interconnected capillaries and tubules in the interior of the matrix; and the open porous interior is to be contrasted with a closed porous interior in which the pores are closed off and are isolated from one another. The number, size and spacing of the pores may be selected accordingly. In particular, the open porous interior of the matrix may comprise pores having an average pore size of 1 - 40 μm, the matrix material, excluding the volumes of the passages, having a percentage

porosity of 30 - 70%, preferably 40 - 60%, eg 50%, as defined by the equation:

$$\text{percentage porosity} = 100 \times \frac{\rho_c - \rho_m}{\rho_c}$$

in which ρ_c is the density of the ceramic of the matrix excluding any passages or pores; and
ρ_m is the bulk density of the matrix as a whole, excluding any passages but including the pores.

It is contemplated that, in use in accordance with the present invention, a suitable catalyst for the conversion of undesirable pollutants in combustion gases such as flue gases or exhaust gases from internal combustion engine exhausts of the petrol- or gasoline-derived type, will be supported by the catalyst support of the present invention, to provide a core for a catalytic convertor according to the present invention.

Thus, according to the present invention, the support may comprise a catalyst for the treatment of combustion gases by catalytic conversion of undesirable components of said gases into a less undesirable form, the catalyst being supported on the surfaces of any passages extending along the interior of the matrix and on the surfaces of the pores in the porous interior of the matrix. In this case, the interior of the matrix may thus have a plurality of passages extending along its interior in a direction which extends from an end of the support towards another end of the support, each passage opening out of at least one end of the matrix and a plurality of the passages opening out of each end of the matrix, at least some of the passages being constricted by constrictions at positions closer to the one end of the matrix than to the other end of the matrix and opening out of said other end of the matrix, and at least some of the passages being constricted by constrictions at

positions closer to said other end of the matrix than to said one end of the matrix and opening out of said one end of the matrix, the constrictions of the passages acting to promote flow of gas entering the open ends of constricted passages at the end of the matrix remote from their constrictions, in a direction transverse to the passages and through the porous interior of the matrix material and into passages having open ends at the opposite end of the matrix and remote from their constrictions, and thence out of the matrix via said open ends at the opposite end of the matrix, the support, with the catalyst supported on the surfaces of the passages and in the pores on the surfaces of the pores in the porous interior of the matrix forming a core for a catalytic convertor.

Routine experimentation will be employed to determine a suitable catalyst density, ie mass of catalyst/unit volume of support or number of catalytically active sites/unit volume of support, for effective catalytic conversion, and for a platinum/rhodium (Pt/Rh) catalyst of the type commonly used for this purpose, it is expected that a more or less conventional catalyst density may be used. In particular, the material of the matrix may be α-alumina,the catalyst comprising platinum (Pt) and rhodium (Rh), and being suitable for the catalytic conversion of combustion gases in the form of exhaust gases from an internal combustion engine.

The invention extends also to a catalytic convertor which comprises a core as described above, located in a suitable housing, eg a steel housing of the type typically used and for this purpose, optionally of the type of material used for internal combustion engine silencers, the housing having an exhaust gas inlet at one end thereof and an exhaust gas outlet at the opposite end thereof, the housing fitting in substantially airtight fashion around the core so that no more than a negligible amount

of exhaust gas can flow through from the inlet of the housing to the outlet of the housing around the core, without passing through the core. In other words, the matrix may be located in a metal housing, the housing having opposite ends provided respectively with openings which provide respectively an exhaust gas inlet and an exhaust gas outlet, the matrix being arranged in the housing in a fashion which causes at least a major proportion of any exhaust gases entering the inlet to pass through the interior of the core, via the ducts and pores thereof, before issuing from the outlet. In this case, the housing may fit snugly around the core so that there is a substantially airtight seal between the outer surface of the core and the inner surface of the housing, and so that no more than a negligible proportion of any exhaust gases entering the inlet can flow from the inlet to the outlet without passing through the interior of the core.

It is contemplated that, in accordance with the invention, the matrix may be made by moist consolidation, eg extrusion, of a more or less mono-sized particulate ceramic material such as α-alumina of a suitable particle size, eg 3 - 60 μm, preferably 10 - 30 μm, eg 20 μm, to form a compact or extrusion with the passages therein, followed by drying and sintering, eg as described in the Applicants co-pending South African Complete Patent Applications Nos. 97/4227 and 97/4228. Catalyst deposition, which may be effected in any suitable fashion, such as from a solution or from the gas phase, or by means of the sol/gel method, may be carried out on at least some of the particles, eg particles of α-alumina, before the consolidation, and/or on the consolidated support, before or after the sintering, so as to deposit catalyst both in the porous interior of the matrix of the support, and also on the surface of the passages extending along the interior of the support.

The invention will now be described, by way of example, with reference to the accompanying drawing and proposed Example. In the drawing:

Figure 1 shows a schematic longitudinal section of a catalytic convertor comprising a core and housing, according to the invention, in the direction of line I - I in Figure 2; and

Figure 2 shows a schematic cross-section of the convertor of Figure 1, in the direction of line II-II in Figure 1.

In the drawings, reference numeral 10 generally designates a catalytic convertor in accordance with the present invention. The catalytic convertor comprises, broadly, a catalyst support in the form of a core, generally designated 12, and a housing, generally designated 14.

The housing is of mild steel of the type typically employed for internal combustion engine silencers, and is circular in cross-section, having a cylindrical body portion 16 of constant diameter, an inlet 18, an outlet 20 and two frusto-conical tapering portions 22, 24 leading respectively from the inlet 18 to the body portion 16, and from the body portion 16 to the outlet 20.

The core 12 comprises a porous α-alumina sintered ceramic matrix 26 of circular cross-section and right-cylindrical shape, which is an airtight snug fit inside the cylindrical body portion 16 of the housing 14.

The matrix 26 of the core 12 has a multiplicity of circular passages 28 extending along its length, parallel to one another and parallel to the polar axis of the core, and more or less evenly spaced from one another.

Half the passages 28, designated 28.1 in the enlargements showing details of Figure 1, open out of the downstream end surface 30

of the core 12, the remaining half of the passages 28, designated 28.2 in said enlargements, opening out of the upstream end surface 32 of the core 12. The upstream ends of the passages 28.1 are blocked or closed off by non-porous α-alumina closure panels 34, and the downstream ends of the passages 28.2 are similarly closed off by closure panels 36 of the same type.

Instead of being non-porous closure panels 34, 36, the panels 34, 36 may be of the same porous material as the remainder of the matrix 26 of the core 12. A further possibility is to provide each panel 34, 36 with a central opening, so that the panel merely throttles the associated passage instead of blocking it, the central openings (not shown) of the panels 36 acting as exits for any soot or other particles which may form in or enter the associated passages 28.2.

In the catalytic convertor 10 illustrated in the drawings, the core has a diameter of about 150 mm, and a length of about 100 mm, the passages 28 having a diameter of about 3 mm, the drawing being approximately, but not necessarily completely, to scale.

The passages 28.1, 28.2 are arranged so that, in general, each passage 28.1 is more or less surrounded by passages 28.2, and so that each passage 28.2 is more or less surrounded by passages 28.1, although this result, naturally, cannot be fully achieved adjacent the outer curved surface of the core 12.

In Figure 2 the passages are shown arranged in rows extending more or less radially relative to the core 12, the rows being of different lengths, and there being more rows at the periphery of the core 12 than towards its centre. It will be appreciated, however, that, instead, the

passages 28 can be arranged in a rectangular grid arrangement or a hexagonal grid arrangement.

The porous interior of the matrix 26 is occupied by open interconnected pores in the form of microscopic passages or channels (not shown), having a pore size of about 7 μm, the matrix as a whole having a percentage porosity of about 50%. The matrix 26 can be made by extruding a moist mass of α-alumina particles, which are more or less mono-sized and of a particle size of about 20μm, to form a consolidated moist core which can then be dried and sintered, eg as described in the Applicant's co-pending South African Patent Applications Nos. 97/4227 and 97/4228.

Typically the core 12 will contain, both on the porous surfaces of the passages 28, out of which the pores in the interior of the matrix 26 open, and also in the actual pores of the porous interior of the matrix 26, catalytic sites formed by a platinum/rhodium catalyst deposited in said pores and on said porous surfaces of the passages 28. Catalyst deposition can be effected in conventional fashion, at a catalytic site density which is suitable for the intended purpose of the catalytic convertor.

It is an advantage of the invention that, because, the material of the matrix 26 is porous, the spacing between adjacent passages 28, ie the thickness of matrix material between the passages 28, can be varied with substantial flexibility. Accordingly, relatively large passage spacings and relatively large material thicknesses, which can provide mechanical strength and can assist in extrusion, are not necessarily an unacceptable disadvantage in use.

Catalyst deposition can take place on the particles of α-alumina before extrusion, drying and sintering, on at least some of the particles, and/or catalyst deposition can take place after sintering.

In use, in contrast with catalytic convertors having cores comprising passages which are open at opposite ends thereof and are of constant diameter, in which straight-through flow of exhaust gas takes place, the present invention eliminates or at least substantially reduces such straight-through gas flow, in favour of a more tortuous gas flow where gas entering the core 12 via the upstream ends of passages 28.2 flows in a direction transverse to the passages, through the porous material between the passages, and into the passages 28.1 opening out of the downstream end of the core 12, from which passages 28.1 they issue into the tapered portion 24 of the housing 14 prior to issuing from the housing 14 via the outlet 20.

It is a further feature of the invention, accordingly, that intimate contact between the exhaust gases and the material of the core takes place, promoting contact of the exhaust gases with the catalytic sites and promoting effective catalytic conversion of undesirable combustion products in the exhaust gases to more desirable combustion products such as carbon dioxide and water.

CLAIMS:

1. A ceramic catalyst support for supporting a catalyst for the catalytic conversion of a substance passing through the support, the support comprising a ceramic matrix which has an open porous interior comprising open-ended pores, the support having a plurality of passages extending along its interior in a direction which extends from an end of the support towards another end of the support, each passage opening out of at least one end of the matrix and a plurality of the passages opening out of each end of the matrix, at least some of the passages being constricted by constrictions at positions closer to the one end of the matrix than to the other end of the matrix and opening out of said other end of the matrix, and at least some of the passages being constricted by constrictions at positions closer to said other end of the matrix than to said one end of the matrix and opening out of said one end of the matrix, the constrictions of the passages acting to promote flow of gas entering the open ends of constricted passages at the end of the matrix remote from their constrictions, in a direction transverse to the passages and through the porous interior of the matrix material and into passages having open ends at the opposite end of the matrix and remote from their constrictions, and thence out of the matrix via said open ends at the opposite end of the matrix.

2. A ceramic catalyst support supporting a catalyst for the catalytic conversion of substances passing through the support, the support comprising a ceramic matrix which has an open porous interior comprising open-ended pores, and the support comprising a catalyst for the catalytic conversion of substances passing through the support, the catalyst being supported by the support in the pores on the surfaces of the pores in the porous interior of the matrix.

3. A support as claimed in claim 1 or claim 2, the support having a plurality of passages extending along its interior in a direction which extends from an end of the support towards another end of the support, each passage opening out of at least one end of the matrix and a plurality of the passages opening out of each end of the matrix, at least some of the passages being constricted by constrictions at positions closer to the one end of the matrix than to the other end of the matrix and opening out of said other end of the matrix, and at least some of the passages being constricted by constrictions at positions closer to said other end of the matrix than to said one end of the matrix and opening out of said one end of the matrix, the constrictions of the passages acting to promote flow of gas entering the open ends of constricted passages at the end of the matrix remote from their constrictions, in a direction transverse to the passages and through the porous interior of the matrix material and into passages having open ends at the opposite end of the matrix and remote from their constrictions, and thence out of the matrix via said open ends at the opposite end of the matrix, and the support comprising a catalyst for the catalytic conversion of substances passing through the support, the catalyst being supported by the support in the pores on the surfaces of the pores in the porous interior of the matrix.

4. A support as claimed in claim 1 or claim 3, in which substantially half the passages open out of one end of the matrix, the passages extending to the other end of the matrix, at which other end of the matrix they are closed off, the remaining substantially half of the passages opening out of said other end of the matrix and extending substantially all the way to said one end of the matrix, where they are closed off, the passages all being of the same cross-sectional area which is constant along their lengths and all being of the same cross-sectional outline, the passages all being substantially equally spaced from one another and extending alongside one another between the ends of the

matrix, the passages being arranged so that, except adjacent a surface of any side of the matrix between its ends, each tube opening out of the one end of the matrix is surrounded by tubes opening out of the other end of the matrix and each tube opening out of the other end of the matrix is surrounded by tubes opening out of the one of the matrix, the passages adjacent the surface of any side of the matrix being only partially so surrounded.

5. A support as claimed in claim 4, in which the matrix has a circular cross-section, and a diameter of 50 -150 mm, the matrix having a length of 50 - 200 mm, the passages having a circular cross-section and a diameter of 2 - 10 mm, the passages being equally spaced from one another by a spacing, between adjacent passages, of 1 -10 mm.

6. A support as claimed in any one of claims 1 - 5 inclusive, in which the open porous interior of the matrix comprises pores having an average pore size of 1 - 40 μm, the matrix material, excluding the volumes of the passages, having a percentage porosity of 30 - 70%, as defined by the equation:

$$\text{percentage porosity} = 100 \times \frac{\rho_c - \rho_m}{\rho_c}$$

in which: ρ_c is the density of the ceramic of the matrix, excluding any passages or pores; and

ρ_m is the bulk density of the material of the matrix as a whole, excluding any passages but including the pores.

7. A support as claimed in any one of claims 1 - 6 inclusive, which comprises a catalyst for the treatment of combustion gases by catalytic conversion of undesirable components of said gases into a less undesirable form, the catalyst being supported on the surfaces of any passages extending along the interior of the matrix and on the surfaces of the pores in the porous interior of the matrix.

8. A support as claimed in claim 7, in which the interior of the matrix has a plurality of passages extending along its interior in a direction which extends from an end of the support towards another end of the support, each passage opening out of at least one end of the matrix and a plurality of the passages opening out of each end of the matrix, at least some of the passages being constricted by constrictions at positions closer to the one end of the matrix than to the other end of the matrix and opening out of said other end of the matrix, and at least some of the passages being constricted by constrictions at positions closer to said other end of the matrix than to said one end of the matrix and opening out of said one end of the matrix, the constrictions of the passages acting to promote flow of gas entering the open ends of constricted passages at the end of the matrix remote from their constrictions, in a direction transverse to the passages and through the porous interior of the matrix material and into passages having open ends at the opposite end of the matrix and remote from their constrictions, and thence out of the matrix via said open ends at the opposite end of the matrix, the support, with the catalyst supported on the surfaces of the passages and in the pores on the surfaces of the pores in the porous interior of the matrix forming a core for a catalytic convertor.

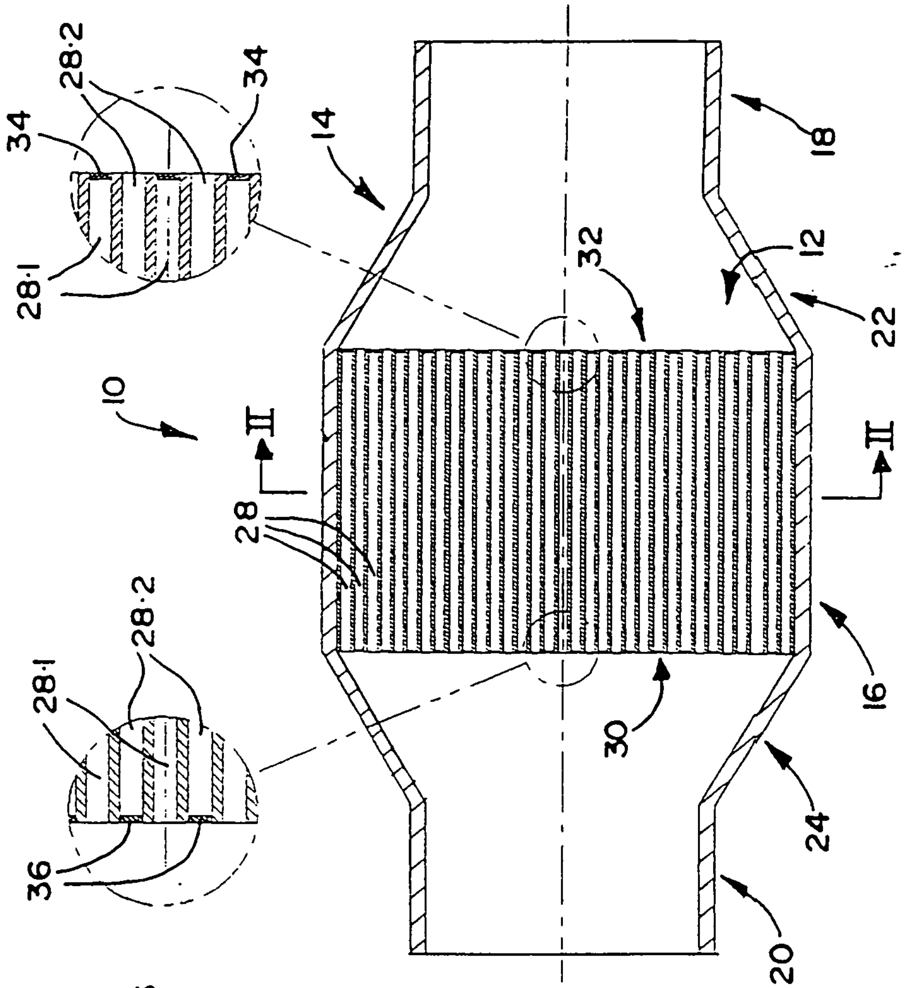
9. A support as claimed in claim 8, in which the material of the matrix is α-alumina, the catalyst comprising platinum (Pt) and rhodium (Rh), and being suitable for the catalytic conversion of combustion gases in the form of exhaust gases from an internal combustion engine.

10. A support as claimed in claim 9, in which the matrix is located in a metal housing, the housing having opposite ends provided respectively with openings which provide respectively an exhaust gas inlet and an exhaust gas outlet, the matrix being arranged in the housing in a fashion which causes at least a major proportion of any exhaust gases entering

the inlet to pass through the interior of the core, via the ducts and pores thereof, before issuing from the outlet.

11. A support as claimed in claim 10, in which the housing fits snugly around the core so that there is a substantially airtight seal between the outer surface of the core and the inner surface of the housing, and so that no more than a negligible proportion of any exhaust gases entering the inlet can flow from the inlet to the outlet without passing through the interior of the core.

12. A ceramic catalyst support as claimed in claim 1, substantially as herein described and as illustrated with reference to the accompanying drawings.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II

FIG 1

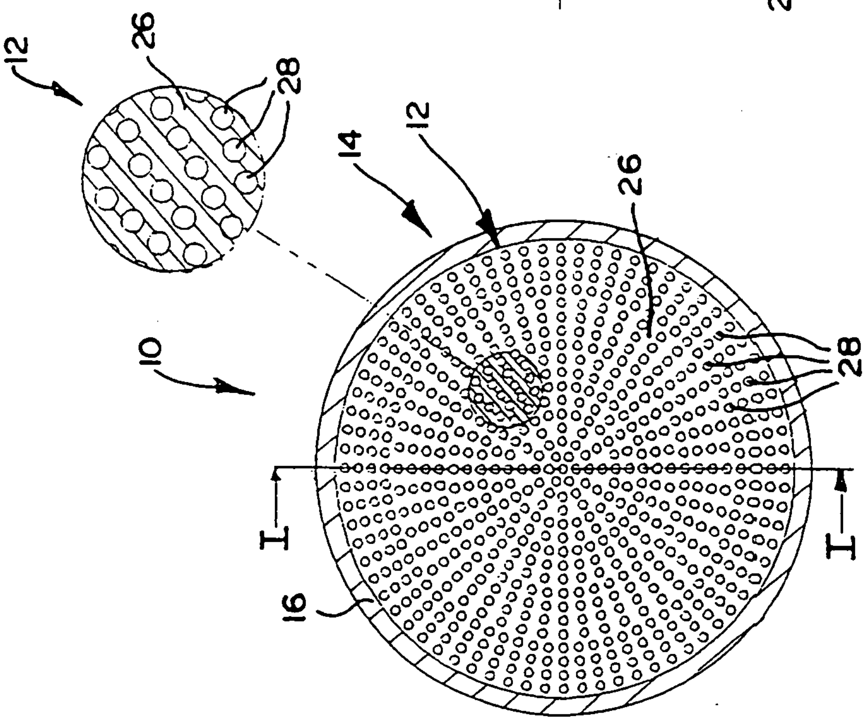
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FIG 2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/05479

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F01N3/28 B01J35/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F01N B01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 766 993 A (TOYOTA MOTOR CO LTD) 9 April 1997 see column 5, line 1 - column 7, line 23; figures 1,3-6 ---	2,7
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 378 (M-546), 17 December 1986 & JP 61 169610 A (NIPPON CLEAN ENGINE RES), 31 July 1986 see abstract ---	1,2
A	EP 0 438 603 A (SAKAI CHEMICAL INDUSTRY CO) 31 July 1991 see page 3, line 53 - page 4, line 22; figures see abstract -----	1,2

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 December 1998	21/12/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Torle, E

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 98/05479

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0766993 A	09-04-1997	JP 9094434 A	08-04-1997
EP 0438603 A	31-07-1991	JP 3072916 A	28-03-1991
		WO 9101795 A	21-02-1991
		US 5180567 A	19-01-1993